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Geotechnical and Structures Laboratory

Earthquake Event Report for the North Alabama 29 April 2003 $M_w = 4.6$ Earthquake

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Carters Lake Dam

Buford Dam, Lake Lanier

October 2003

ERDC
Engineer Research and Development Center

Earthquake Event Report for the North Alabama

29 April 2003 M_w = 4.6 Earthquake

Purpose

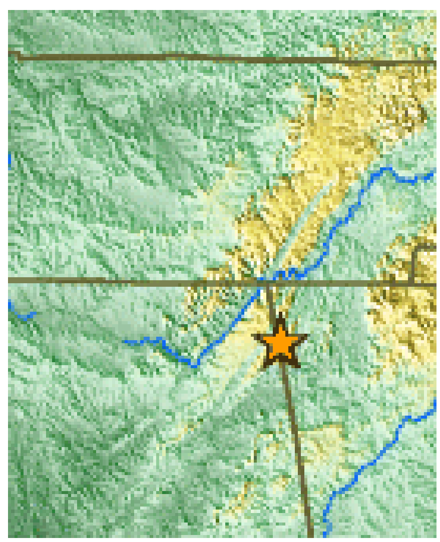
This report documents the earthquake strong-motion accelerograms from the 29 April 2003 08:59:38 (UTC) Alabama earthquake collected and analyzed from the USACE Mobile Engineer District's Carters Lake Dam and Buford Dam – Lake Lanier by the USACE Strong-motion Instrumentation Program (SMIP). The USACE SMIP is executed by the USACE Engineer Research and Development Center (Ballard, 1998).

Earthquake Event Information

This earthquake was reported by several government agencies. The United States Geological Survey (USGS), National Earthquake Information Center (NEIC) web page release:

The following is a release by the United States Geological Survey, National Earthquake Information Center: A light earthquake occurred 25 km (15 miles) ENE of Fort Payne, Alabama at 2:59 AM MDT, Apr 29, 2003 (3:59 AM CDT in Alabama). The magnitude and location may be revised when additional data and further analysis results are available. No reports of damage or casualties have been received at this time.

Depth: 5.0 kilometers
Region: ALABAMA
Reference:
15 km (10 miles) ENE of Fort Payne, Alabama
45 km (25 miles) ESE of Scottsboro, Alabama
50 km (30 miles) NW of Rome, Georgia
Coordinates: 34 deg. 30.5 min. N (34.508N),
85 deg. 36.7 min. W (85.612W)
Source: USGS NEIC



U.S. Department of the Interior, U.S. Geological Survey
URL: http://neic.usgs.gov/neis/bulletin/neic_teak.html

The State of Alabama Geologic Survey web page release:

Tuesday morning April 29, 2003,at 3:59 A.M. a strong earthquake with a magnitude of 4.9 occurred in DeKalb County, Alabama, just east of DeSoto State Park and 10 miles ENE of Fort Payne, Alabama. The quake was fell in eight states and woke people in Tuscaloosa and Montgomery Counties. Only one other earthquake of this strength has been recorded by seismographs in Alabama. That was the 1997 4.9 magnitude earthquake in Escambia County. In recent years there have been numerous small earthquakes in the immediate vicinity of this new quake. Earthquakes in the northeastern part of Alabama are in the Southern Appalachian/East Tennessee Seismic Zone. Earthquakes are common in this area but are generally so small they are not felt. This is the largest earthquake known to have occurred in this seismic zone historically, and is one of the largest earthquakes known to have occurred anywhere in the southern Appalachians.

An updated NEIC determination of this earthquake's magnitude is Mw = 4.6 (source: http://wwwneic.cr.usgs.gov/).

This earthquake is plotted on a seismicity map for 1977 to 1997 prepared by the USGS NEIC showing the earthquake in context to the region's seismicity (Figure 1). As can be seen, this earthquake's location is not unexpected. The adjacent NEIC map shows this $M_W = 4.6$ north Alabama earthquake and five smaller events recorded in the intervening five months with magnitudes ranging from 1.9 to 2.9. The largest reported earthquake for this region is the Irondale, Jefferson County, Alabama 1916 event with an magnitude estimated from felt area of $M_{fa} = 5.1$.

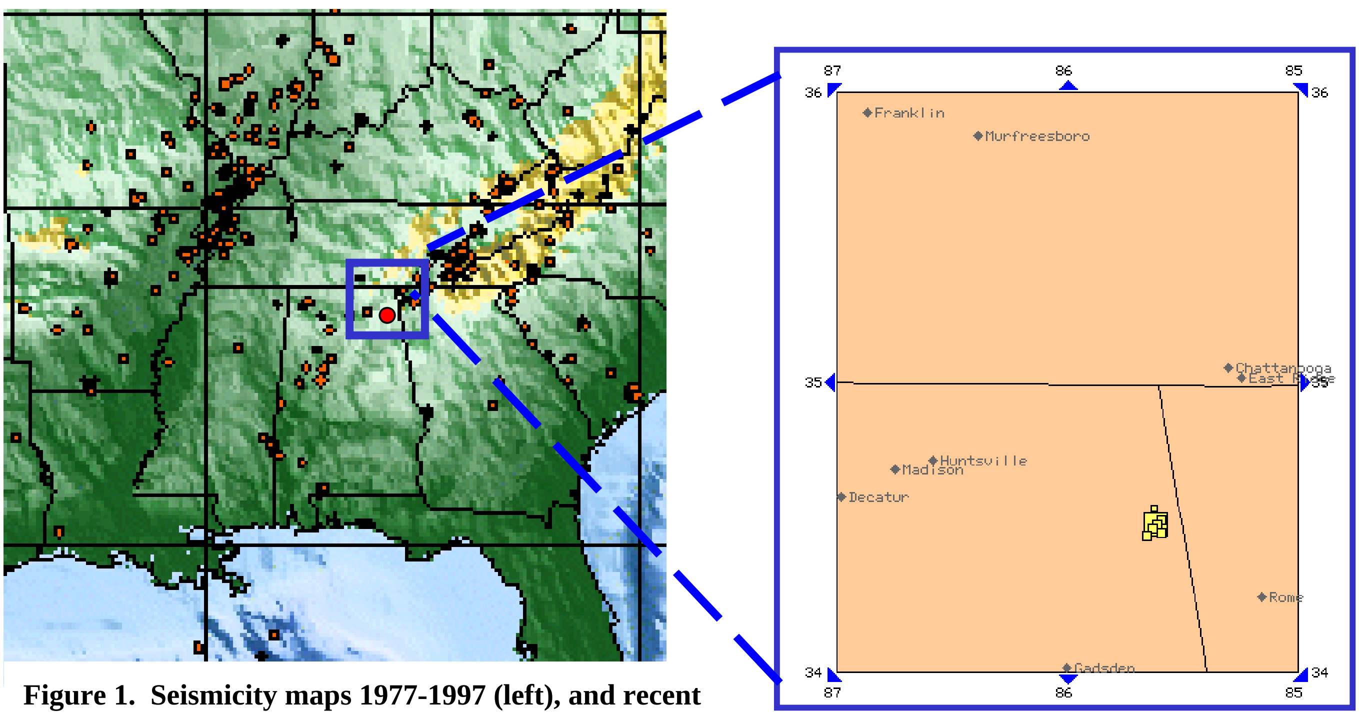


Figure 1. Seismicity maps 1977-1997 (left), and recent seismicity associated with earthquake (right). (USGS NEIC)

Figure 2 presents USACE dams having SMIP stations within a 205 km radius of this earthquake, their tabulated distances to the earthquake epicenter, and which SMIP stations this earthquake triggered. Also plotted on this map is the USGS catalog of earthquake locations up to 1996. The triggered accelerographs were located on the crests of Carters and Buford Dams at epicentral distances of 85 and 146 km, respectively.

SMIP Stations Triggered

Dam	Epicentral Distance (km)
Carters	**85**
Altoona	89
Buford	**146**
Center Hill	178
J H Bankhead	200
J Percy Priest	205

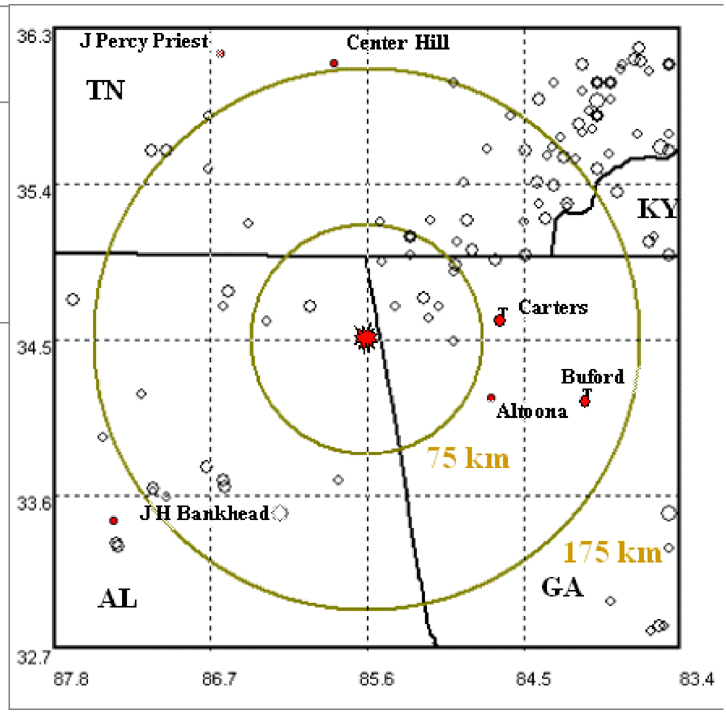


Figure 2 Earthquake Report on North Alabama 29 April 2003 M_w = 4.6 event

Project Descriptions and Instrumentation

Carters Lake Dam was constructed between 1962 and 1977 to provide hydropower, flood control, recreation, and fish and wildlife management. It is the highest earth and rockfill dam east of the Mississippi with a maximum crest height of 446 ft. The northernmost dam on the Alabama-Coosa River System, Carters Dam is located on the Coosawattee River, 60 miles north of Atlanta, GA. The main lake is 3,200 acres with a total storage capacity of 242,200 acre-feet. With flood storage capacity of 95,700 acre-feet, Carters collects runoff from a 375 square mile area watershed.

Strong-motion Accelerograph Locations

Three strong-motion accelerographs are located at the crest, right abutment (adjacent to intake structure), and downstream right abutment of the dam. Each accelerograph is a Kinemetrics model ETNA. The ETNA’s sensor is a Triaxial EpiSensor force balance accelerometer, orthogonally oriented (two horizontal and one vertical channels), with a full scale range of 2 g and a bandwidth of DC to 200 Hz. The overall system response is DC to 80 Hz for the sampling rate of 200 samples per second with 18 bits of resolution with 108 dB dynamic range. The location of these instruments and their orientation with respect to the dam axis are provided in the photograph and plan view shown as Figure 3. Photographs of the stations are also presented in Figure 4. It is interesting to note that accelerographs at Carters Dam were upgraded to digital 17 April — just 11 days before this earthquake, thus enabling collection of much higher quality accelerograms.

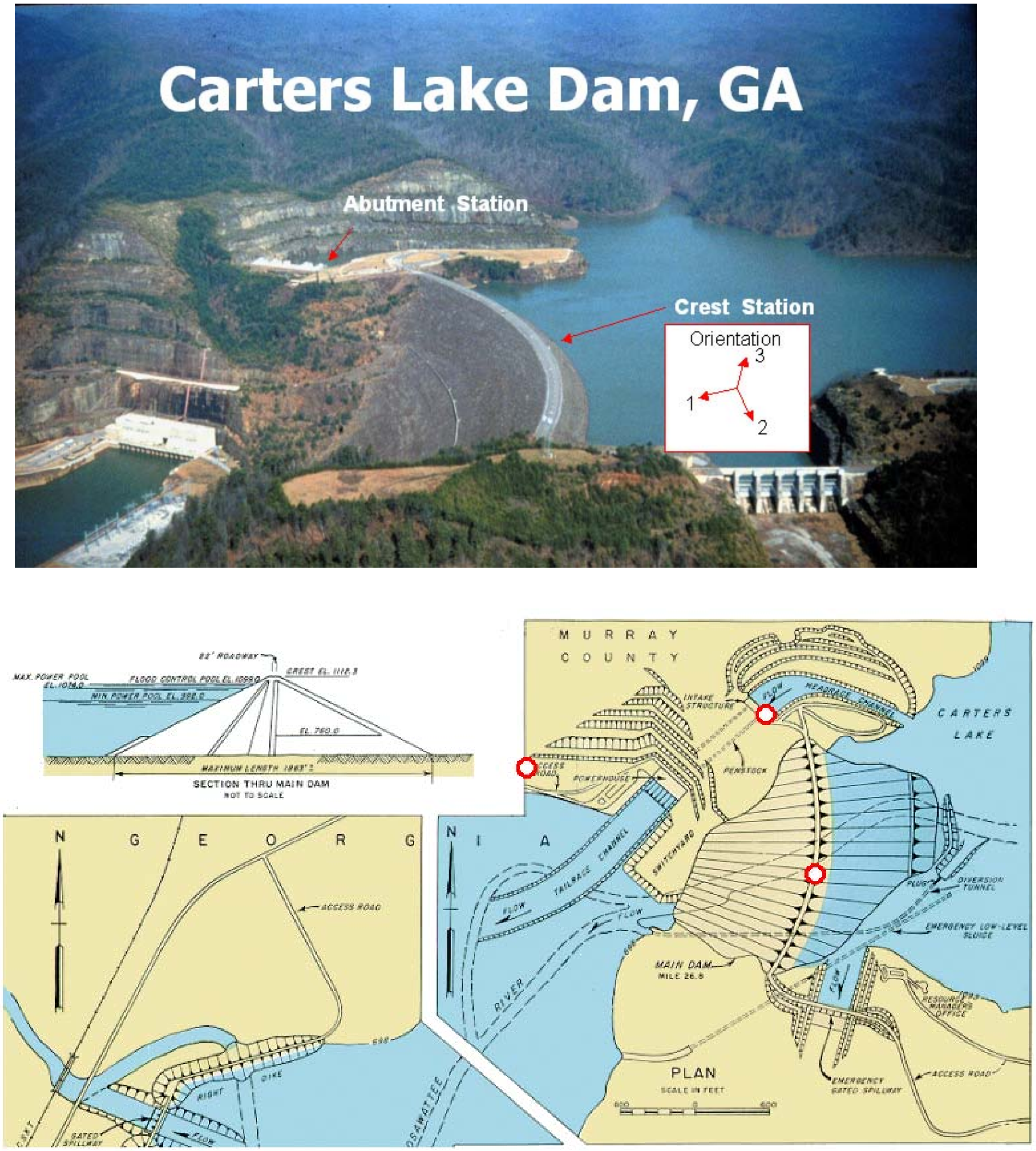


Figure 3. Photograph and plan view showing location of strong-motion instrumentation at Carters Dam, GA.

Carters Crest

Carters Downstream

Carters Crest Abutment Station

Carters Crest

Figure 4. Photographs of stations at Carters Dam.

Buford Dam and Lake Lanier was constructed between 1953 and 1956 and to provide hydropower, flood control, navigation, stream flow regulation, recreation and fish and wildlife management, and water supply. Buford Dam is located on the Chattahoochee River in north-central Georgia about 35 miles northeast of Atlanta and 5 miles northwest of the town of Buford. It consists of an earthen dam founded on the original river channel. The main dam is 192 feet high and 2,360 feet long. The main lake is 38,200 acres. Buford collects runoff from 1,040 square mile watershed.

Strong-motion Accelerograph Locations

Two strong-motion accelerographs are located on the crest, and a free field station is located in the basement of the Visitors Center upstream of dam. Each accelerograph is a Kinemetrics model ETNA, previously described. The location of these instruments and their orientation with respect to the dam axis are provided in Figure 5. Photographs of the stations are also presented in Figure 6.

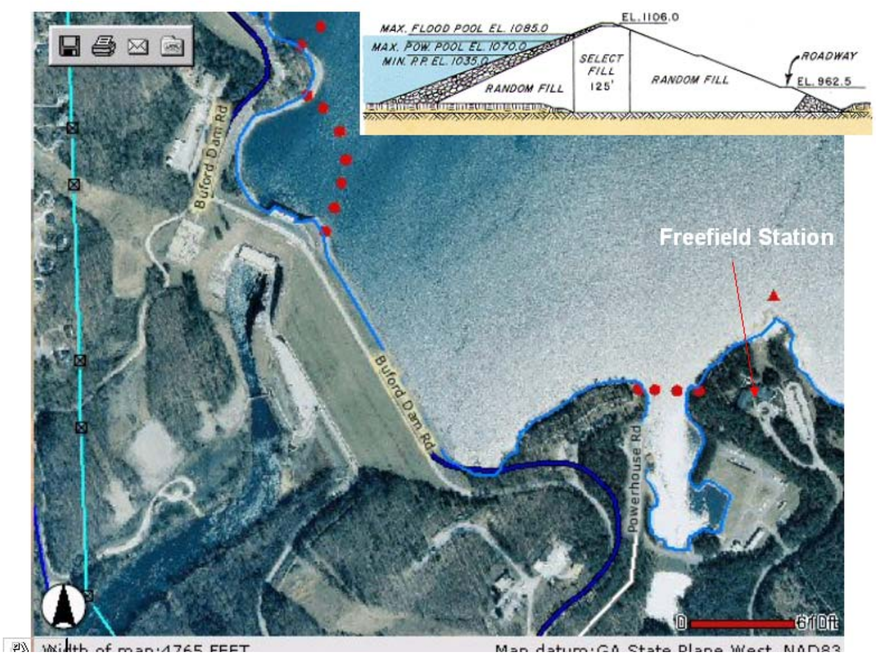


Figure 5. Photographs showing instrument locations at Buford Dam, GA.

Buford Crest Station

Buford Abutment Station: Resource Management Office Basement

Figure 6. Photographs of stations at Buford Dam.

Data Analysis

This earthquake triggered crest accelerographs at both Carters and Buford Dams (see Table 1.) The other accelerographs at these dams were operational but did not trigger. Probably the crest stations were triggered due to the amplification of ground motions by the embankment. Whereas the other stations were located on hard rock or foundations founded on hard rock and didn’t experience amplification, and therefore were not of sufficient amplitude to trigger these accelerographs. Also, for the same reason, the accelerographs at Altoona Dam did not trigger even though they are located at a distance intermediate to the triggered instruments. Altoona Dam is a concrete dam and all instruments are located on a structure that did not amplify the passing earthquake ground motions.

USACE SMIP Sites Triggered During 29 April 2003 4.6 Earthquake								
Station	**State**	**Type**	**H (m)**	**Recorder Type**	**Ser. No.**	**Location**	**Coordinates**	**Triggered**
Buford (Lanier)	GA	Earth	70	ETNA	2138	Basement, Visitor Center		
Buford (Lanier)	GA	Earth	70	ETNA	2139	Crest	34.15997 N 84.07369 W	Yes
Carters	GA	Earth & rock	136	ETNA	3544	Downstream		
Carters	GA	Earth & rock	136	ETNA	3545	Right Abutment	34.616 N 84.673 W	
Carters	GA	Earth & rock	136	ETNA	3546	Crest		Yes

Data analysis processing of recorded data was needed to remove instrument response and convert data to engineering units. Data are presented for each channel as time history plots of acceleration, acceleration response spectra, and tri-partite plots (combined plots of acceleration, velocity, and displacement). These data are presented in Figures 7-15 for Buford Dam and Figures 16-24 for Carters Dam.

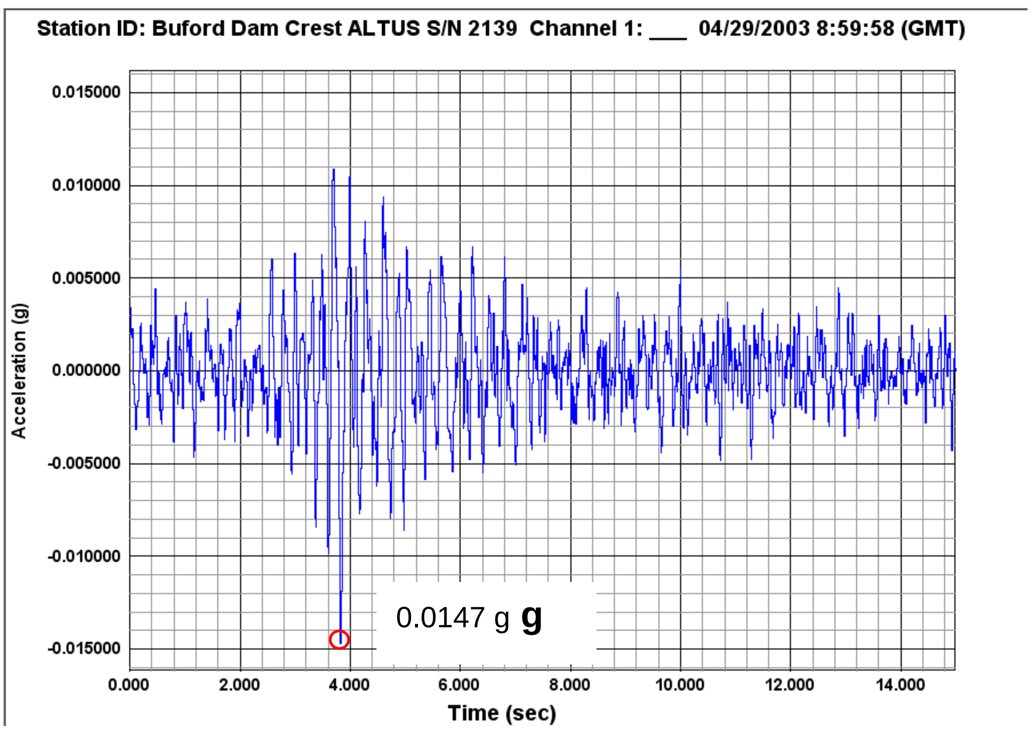


Figure 7. Recorded Accelerogram at Buford Dam, GA - Crest Station Channel 1 Horizontal

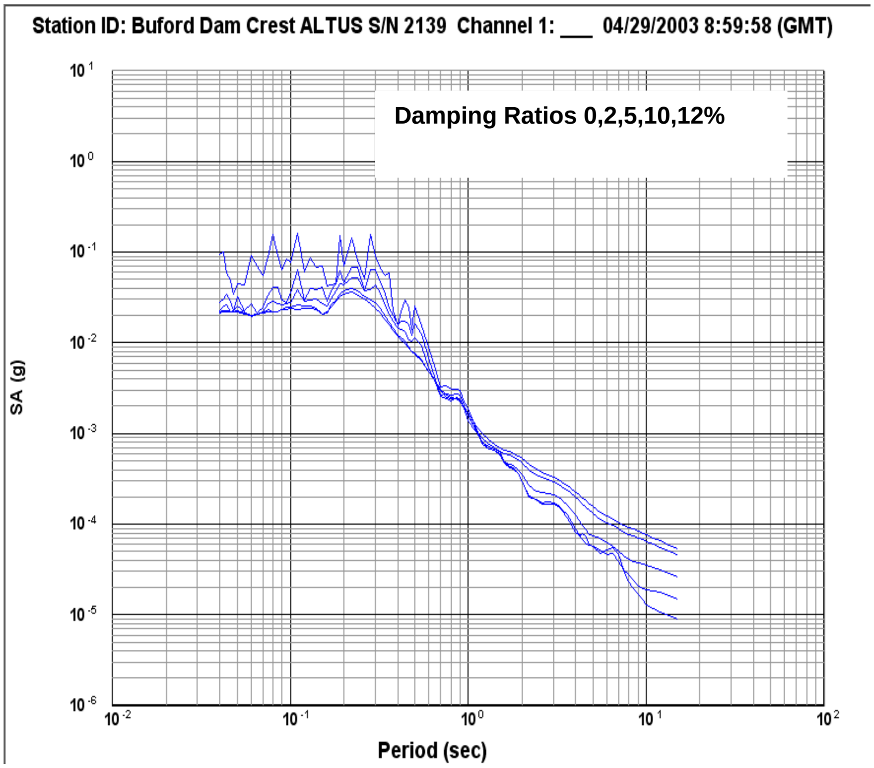


Figure 8. Response spectra at Buford Dam, GA - Crest Station Channel 1 Horizontal

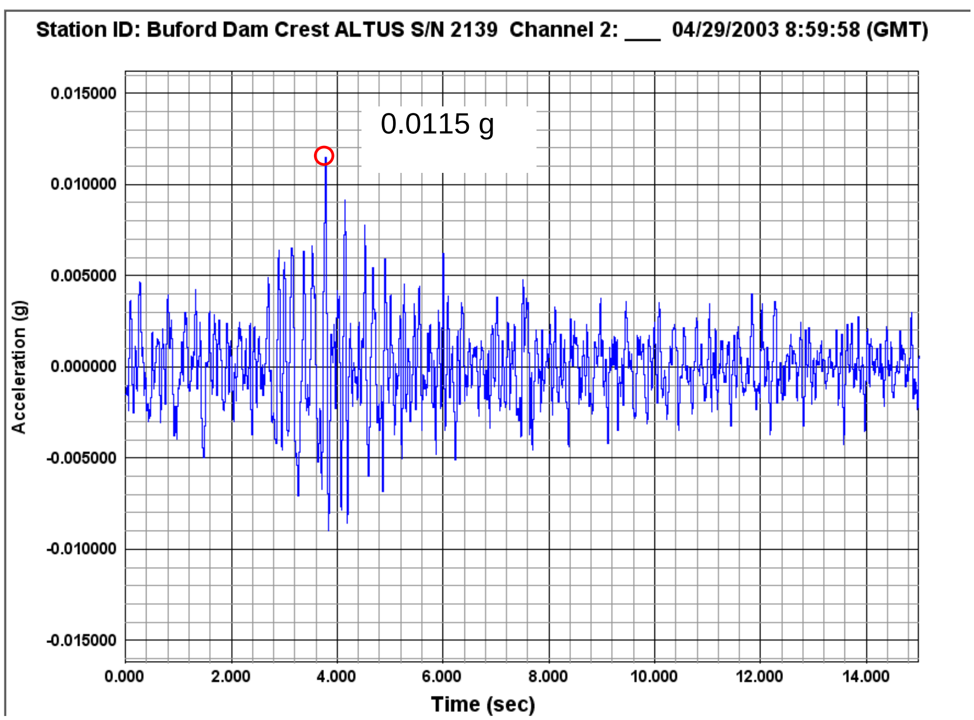


Figure 9. Recorded Accelerogram at Buford Dam, GA - Crest Station Channel 2 Horizontal

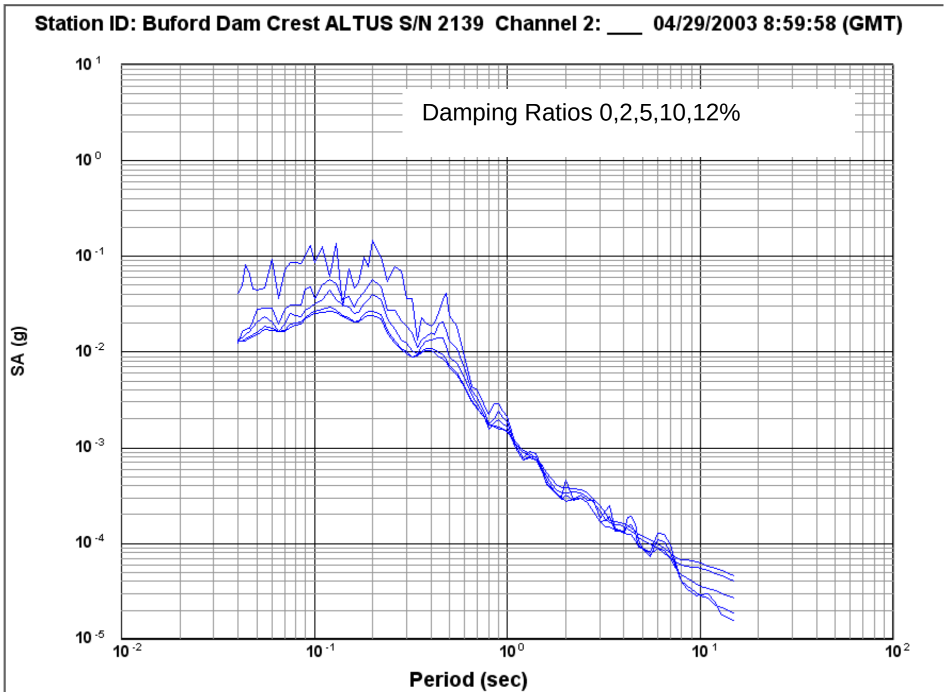


Figure 10. Response Spectra at Buford Dam, GA - Crest Station Channel 2 Horizontal

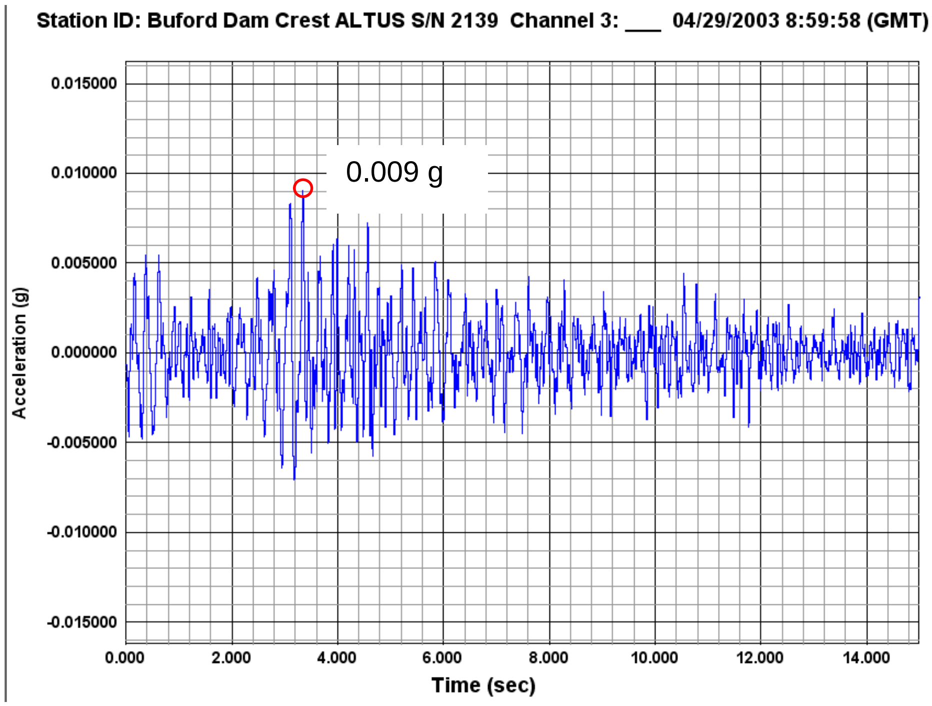


Figure 11. Recorded Accelerogram at Buford Dam, GA - Crest Station Channel 3 Vertical

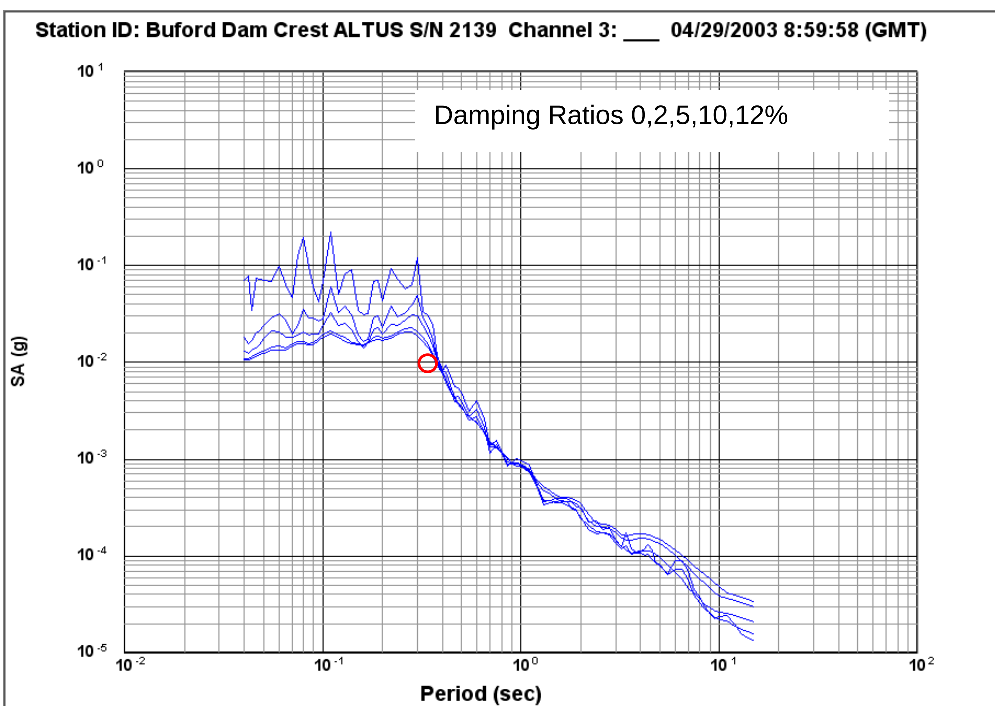


Figure 12. Response Spectra at Buford Dam, GA - Crest Station Channel 3 Vertical

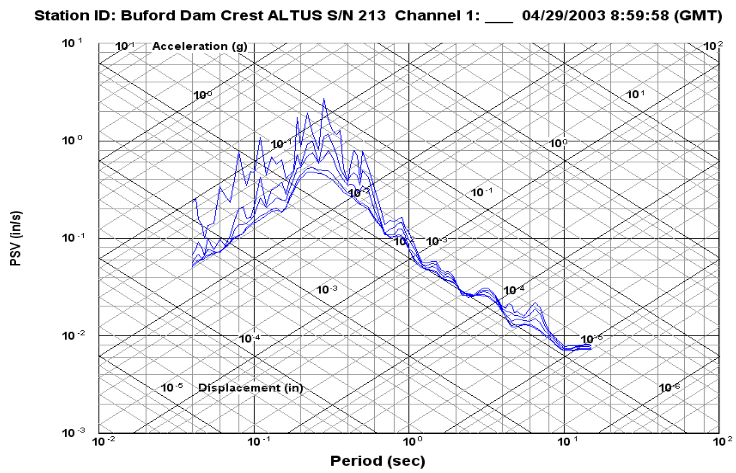


Figure 13. Tripartite plot for Channel 1, Buford Dam Crest.

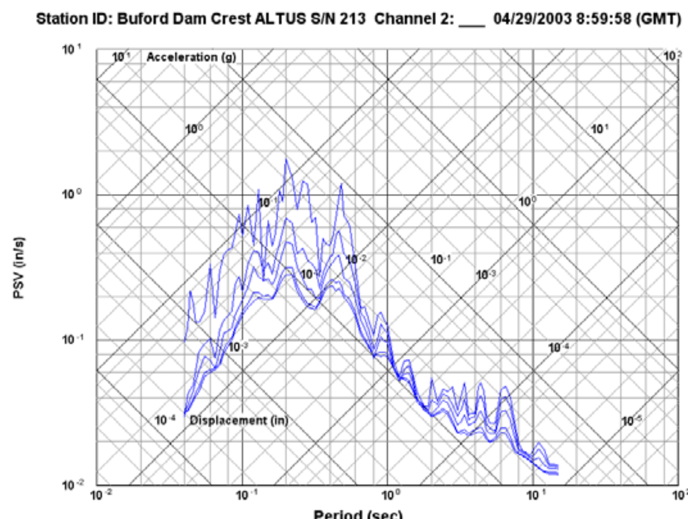


Figure 14. Tripartite plot for Channel 2, Buford Dam Crest.

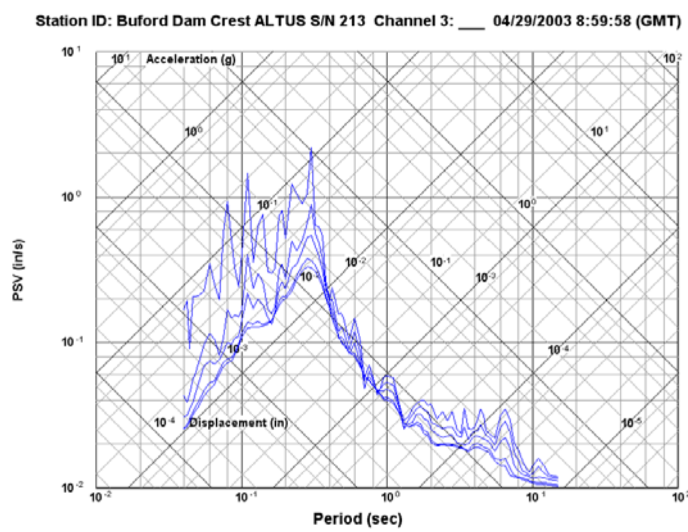


Figure 15. Tripartite plot for Channel 3, Buford Dam Crest.

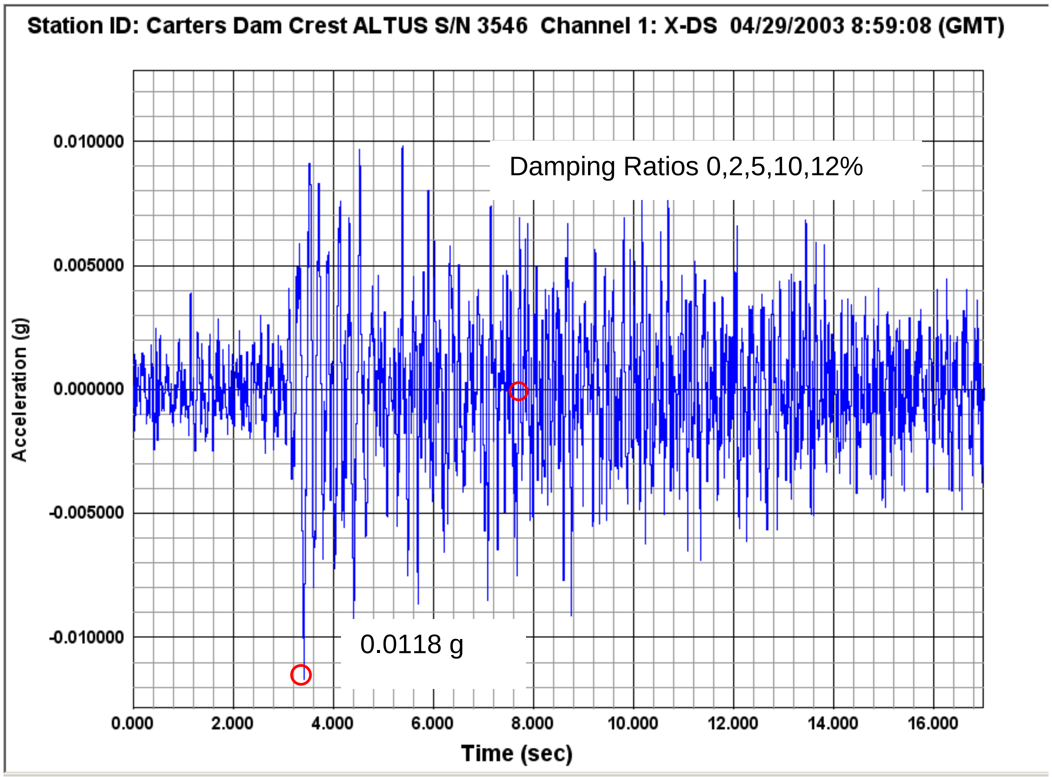


Figure 16. Recorded Accelerogram at Carters Dam, GA - Crest Station Channel 1 Horizontal

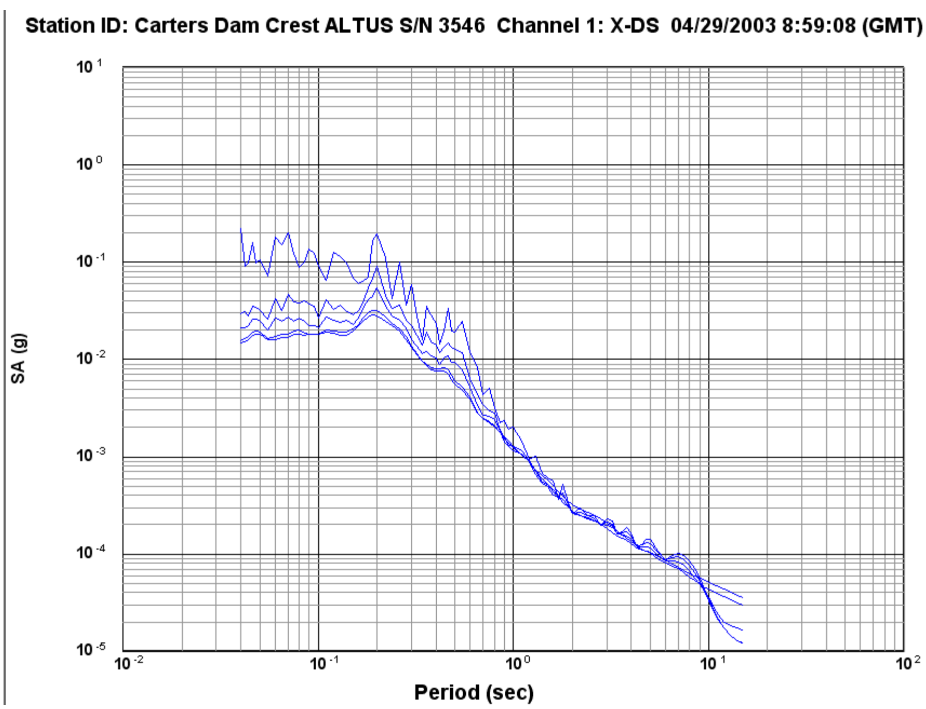


Figure 17. Response Spectra at Carters Dam, GA - Crest Station Channel 1 Horizontal

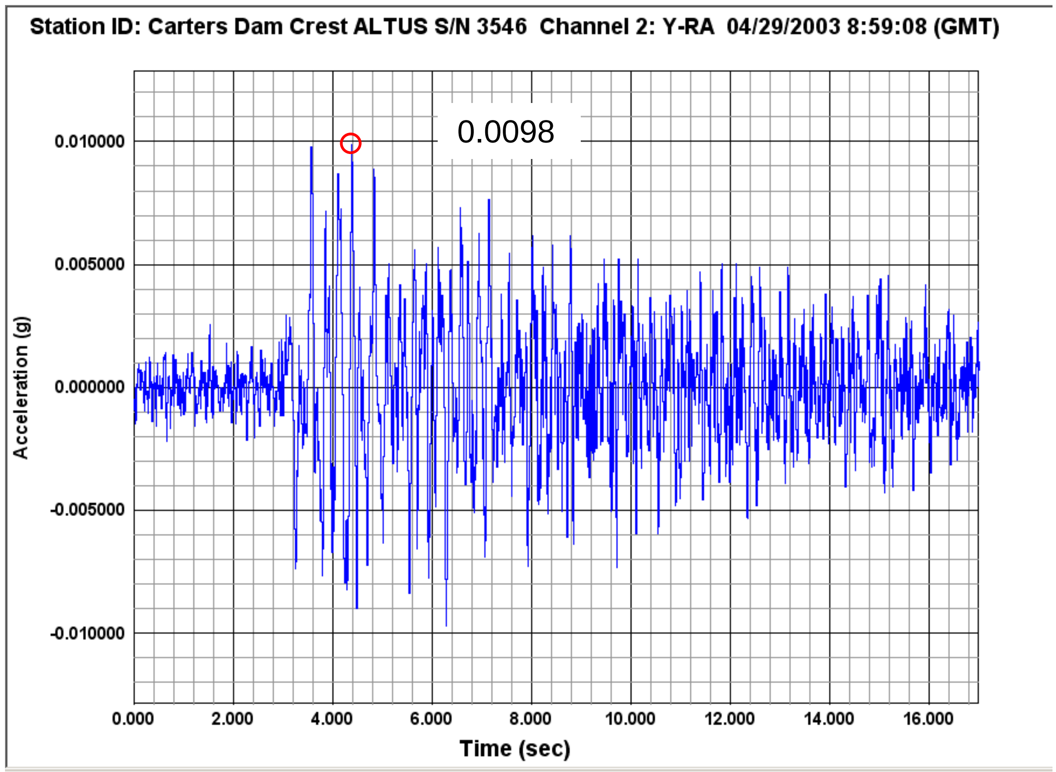


Figure 18. Recorded Accelerogram at Carters Dam, GA - Crest Station Channel 2 Horizontal

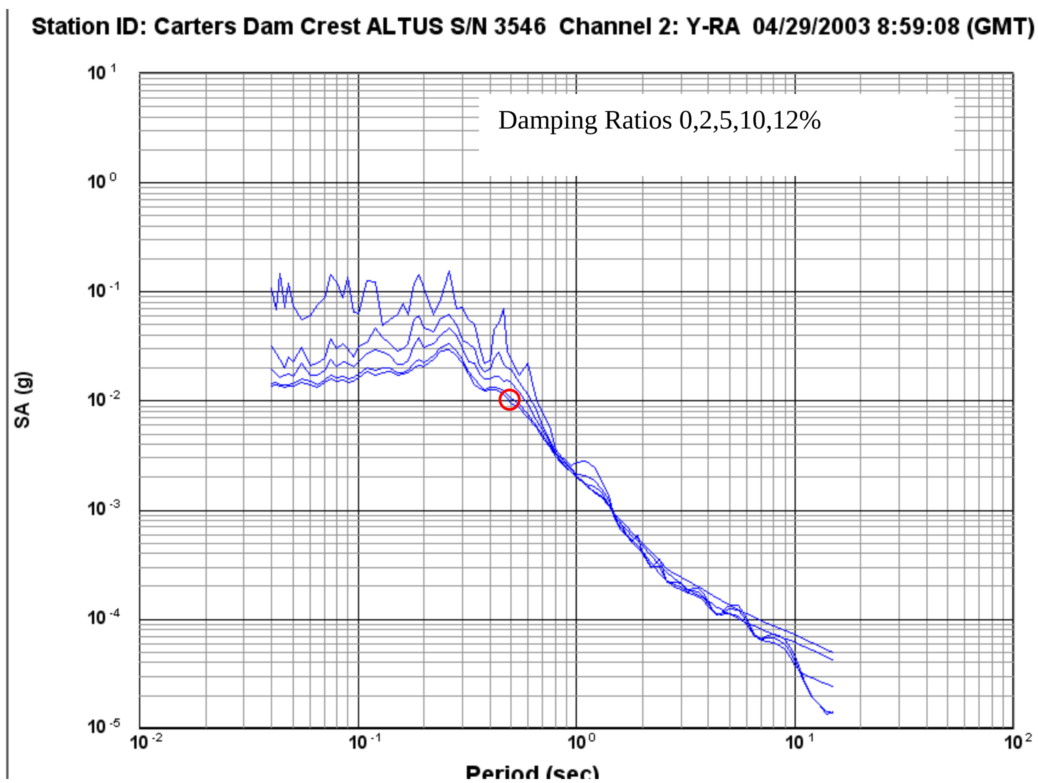


Figure 19. Response Spectra at Buford Dam, GA - Crest Station Channel 2 Horizontal

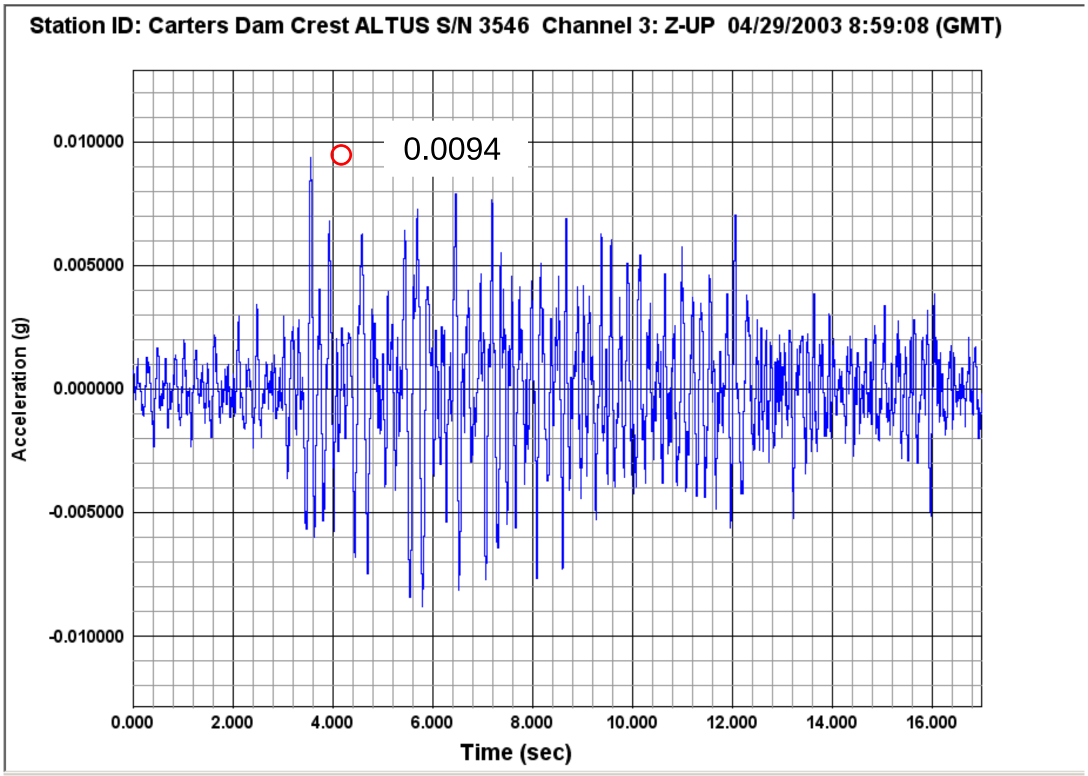


Figure 20. Recorded Accelerogram at Carters Dam, GA - Crest Station Channel 3 Vertical

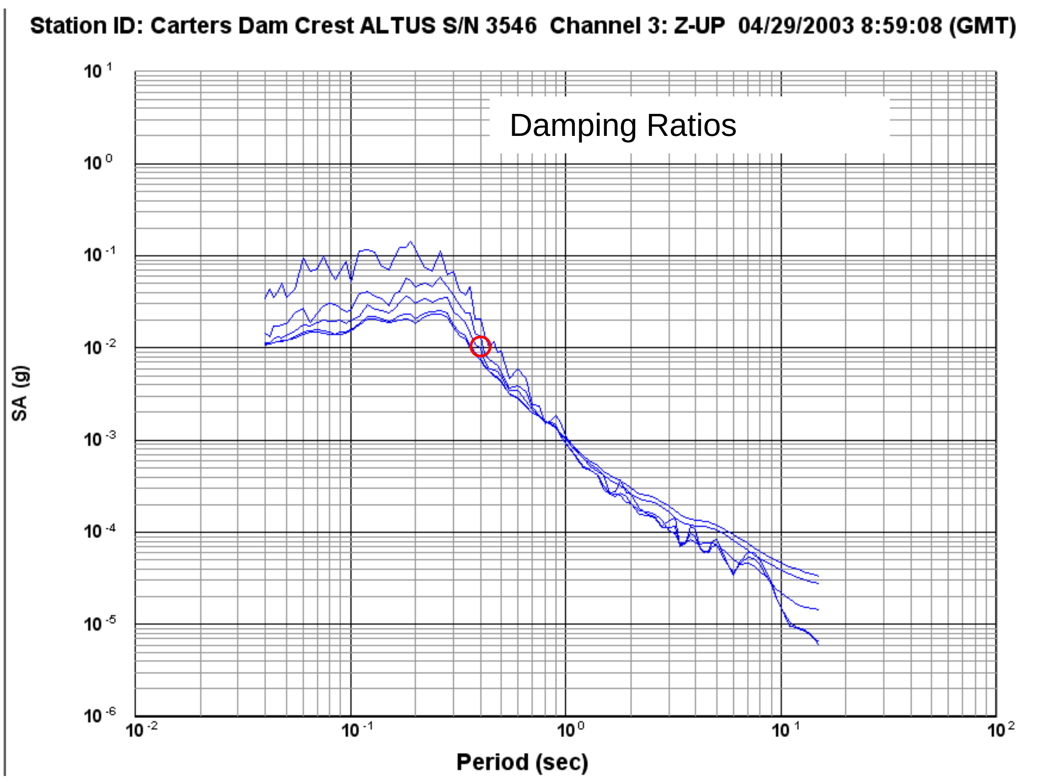


Figure 21. Response Spectra at Carters Dam, GA - Crest Station Channel 3 Vertical

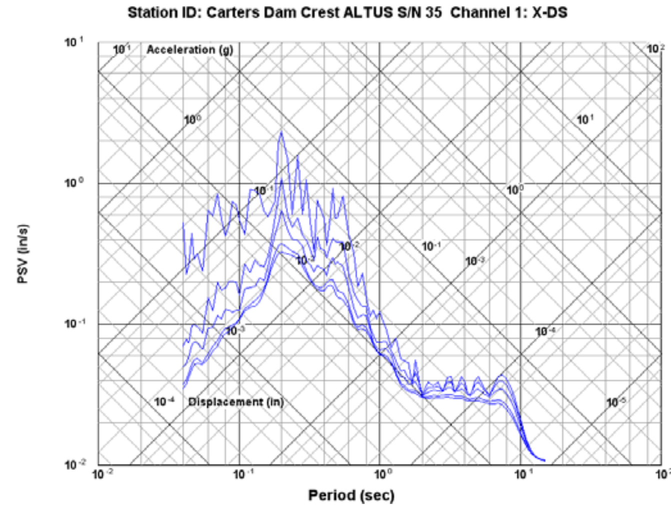


Figure 22. Tripartite plot for Channel 1, Carters Dam Crest.

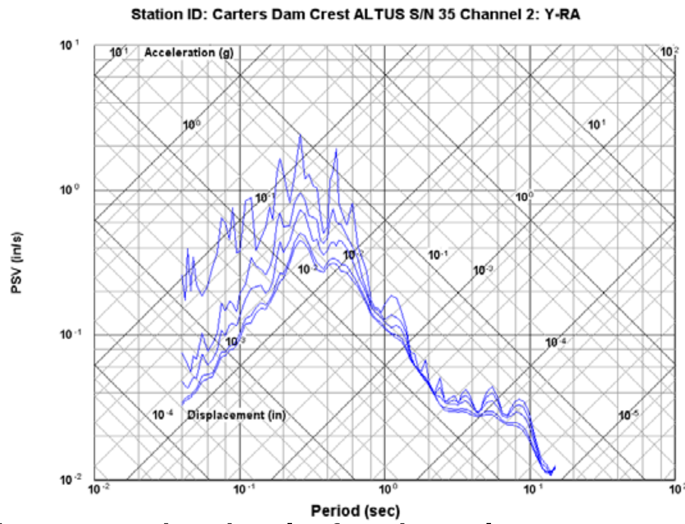


Figure 23. Tripartite plot for Channel 2, Carters Dam

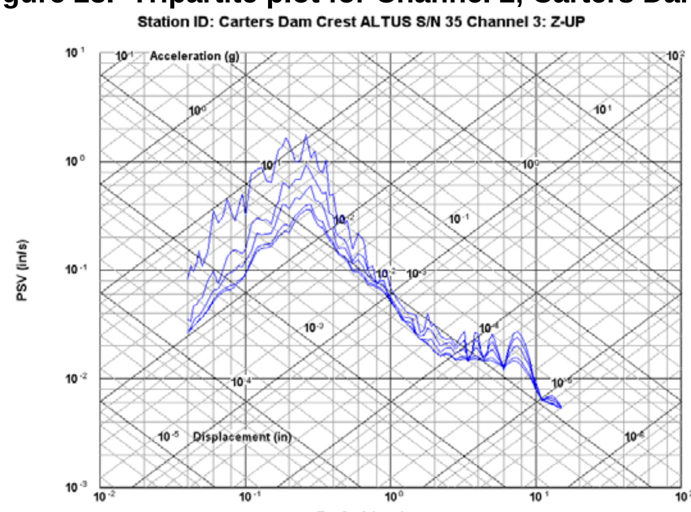


Figure 24. Tripartite plot for Channel 3, Carters Dam

The importance of strong-motion monitoring is to provide post earthquake data for determining earthquake loading to the structure, thus providing a rational basis for any post earthquake inspections or actions and input into future design and analysis of the project. One aspect is to assess whether this event was unexpected, having unusually larger ground motions than considered in the design or from a source that was not considered in determining the site seismic hazard. As discussed previously, current knowledge of regional seismicity sufficiently accounts for this event. This earthquake size is also comparable to the largest historical event for this region. Another consideration is regional attenuation relationships that are used to determine the level of shaking for a given distance from a given size source earthquake. One attenuation relationship applicable to this region is plotted in Figure 25 to enable a comparison between what is expected (mean value) and what was recorded. The attenuation relationship selected, Toro et al and Silva, 1997, is the most recent based on shallow crustal earthquakes in CEUS. This selected attenuation relationship and others are reviewed and documented in the Seismological Research Letters Journal of the Seismological Society of America (Toro et al, 1997). However, this event was a Magnitude M_w = 4.6 and the attenuation relationship is only applicable down to a M_w =5.0 level. Therefore, this comparison is only very approximate as it serves as an upper bound to this size event. Also, the plotted relationship is for a rock site and for conditions where site effects do not dominate. Since these data were recorded at the crest of the dams, we can expect that the resulting ground motions could be a factor of two greater than for a standard rock site. Taking these factors into consideration, we can conclude that the ground motions are not significantly greater than we would expect for this size event at this distance.

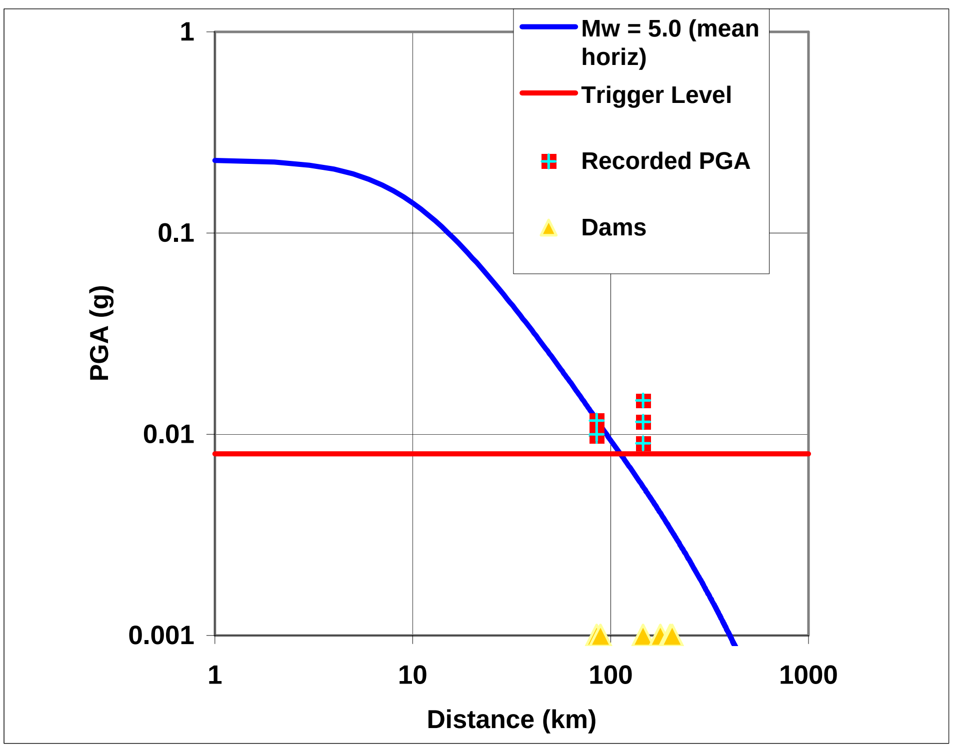


Figure 25. Comparison of Estimated and Recorded Ground Motions.

The next factor to investigate is what level of design is comparable to this earthquake. USACE Engineering Regulation, ER 1110-2-1806, (USACE, 1995) prescribes the development and selection of design earthquake ground motions for two levels of design: a maximum design event (MDE) and an operating basis design earthquakes (OBE). The MDE level uses the Maximum Credible Earthquake arrived by the deterministic method for evaluating critical features of a structure. For non-critical elements, a Maximum Design Earthquake, which is less than the MCE, is used for a maximum design event and can be developed using deterministic and/or probabilistic procedures. An OBE is used for design against economic losses, which specifies an earthquake generated ground motion with a 50% probability of exceedance in the service life of the structure. In this case for a service life of 100 years, the return period is 144 years. Due to the small size of this earthquake, it would be appropriate to compare these ground motions to an OBE design level. Figure 26 presents the OBE level earthquake for the Carters Dam site, which was closest to this earthquake's source. These data were obtained from the probabilistic hazard characterization data developed for the National Seismic Hazard Mapping Project completed in 1996 by the USGS for the National Earthquake Hazard Reduction Program (Frankel et al, 1996). The comparison shows that this earthquake is less than the OBE and no damage should be expected.

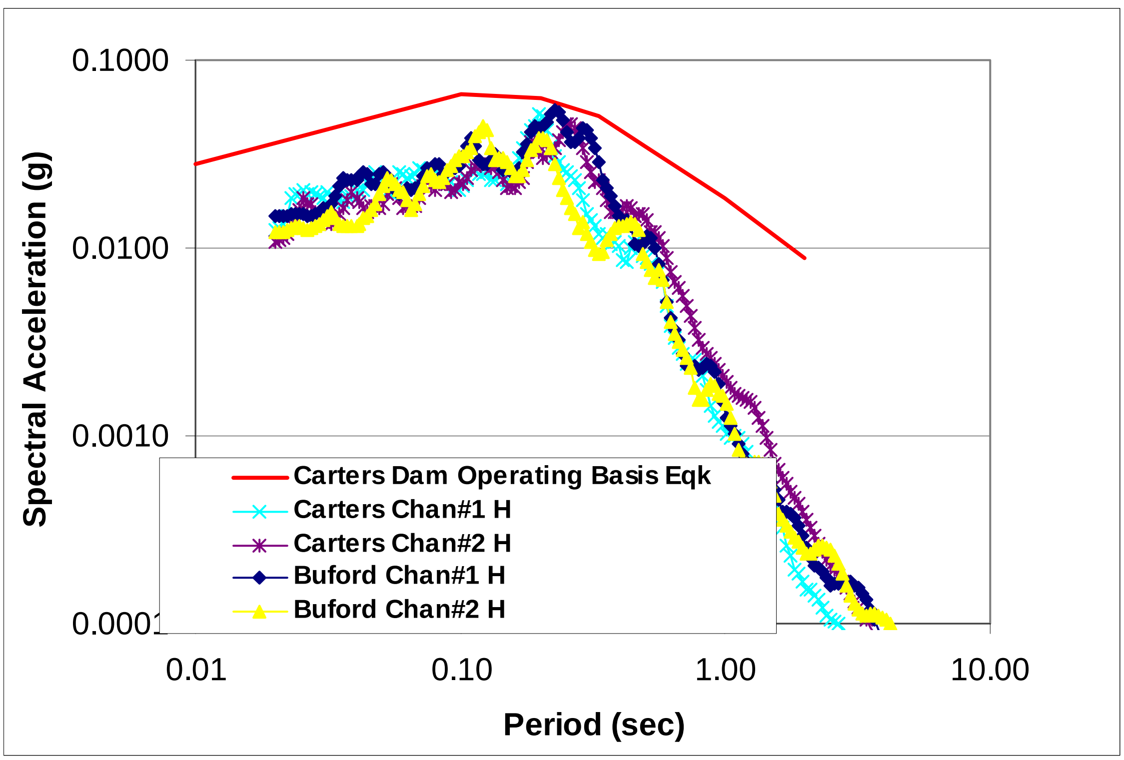


Figure 26. Comparison of OBE Design Earthquake and Recorded Spectra.

Conclusion

As a result of the 29 April 2003 08:59:38 M_w=4.6 earthquake 15 km (10 miles) ENE of Fort Payne, Alabama, two accelerographs were triggered on the crests of Carters and Buford Dams, at a distance of 85 and 146 km, respectively. Although this earthquake was a significant regional event, its location and size are not unexpected. Analysis of the recorded strong-motion data shows that this event is less than the OBE design level from which we can expect no consequential damage to the dam. These strong-motion data are available from the USACE SMIP Program Management office.

References

Ballard, Robert F. Jr., and Grau, Tina H (1998), “ U.S. Army Corps of Engineers Seismic Strong-Motion Instrumentation Program,” Technical Report GL-98-25, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Krinitzsky, Ellis, L. (1995). “State-of-the-Art for Assessing Earthquake Hazards in the United States, Report 29 Selection of Earthquake Ground Motions for Engineering,” Technical Report S-73-1, U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS.

Toro, Gabriel A., Abrahamson, N. A. and Schneider, John F. (1997). Model of Strong Ground Motions from Earthquakes in Central and Eastern North America: Best Estimated and Uncertainties, Seismological Research Letters, Vol. 68, Number 1.

Frankel A. D., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E. V., Hanson, S., and Hopper, M. (1996). A National Seismic Hazard Maps, June 1996 Documentation, Open-File Report 96-532, U. S. Geologic Survey, Golden, CO.

USACE, (1995). Engineering Regulation 1110-2-1806, “ Earthquake Design and Analysis for Corps of Engineers Projects.”

USACE, (1999). Engineering Manual 1110-2-6050, “Response Spectra and Seismic Analysis for Concrete Hydraulic Structures.”

Internet web sites

U.S. Department of the Interior, U.S. Geological Survey –
http://neic.usgs.gov/neis/bulletin/neic_teak.html
http://wwwneic.cr.usgs.gov/
http://geohazards.cr.usgs.gov/eq/

State of Alabama Geological Survey –
http://www.gsa.state.al.us/gsa/GIS/GISHOME.html

USA Engineer Research and Development Center, Geosciences and Structures Division (SMIP) – http://geoscience.wes.army.mil/